Office of Naval Research
Future Naval Capabilities / Advanced Gun Barrel Technology Program
Screening Test Fixture Thermal Analysis

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Agenda

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- AGBT Program
- Thermal Model Description
- Thermal Analysis
- Test Results / Model Calibration
- Path Forward

Background

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Future Naval Capabilities / Advanced Gun Barrel Technology (FNC / AGBT) is being run by the Office of Naval Research (ONR) to upgrade existing barrel capabilities for Naval gun propulsion missions

- One of the FNC / AGBT program objectives is to develop technologies to increase barrel erosion life
  - A task has been funded by the FNC / AGBT program to develop a refractory coated gun barrel for transition into the AGS as part of the spiral design process
    - As part of the refractory coated barrel task a series of screening test were conducted to down select coating materials
      - A thermal analysis, presented herein, was conducted to guide the design of the screening test fixture

Screening Test Fixture

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- A 45 mm gun test fixture was designed, fabricated, & used by United Defense to test refractory coating materials / application processes
  - The test fixture contains a removable insert located at the origin of rifle
  - The inner bore of six inserts were lined with candidate material coatings
  - The inner bore of one insert was lined with chrome
    - Used as a baseline to verify the design of the fixture
  - 50 firings were conducted for each insert

Screening Test Fixture

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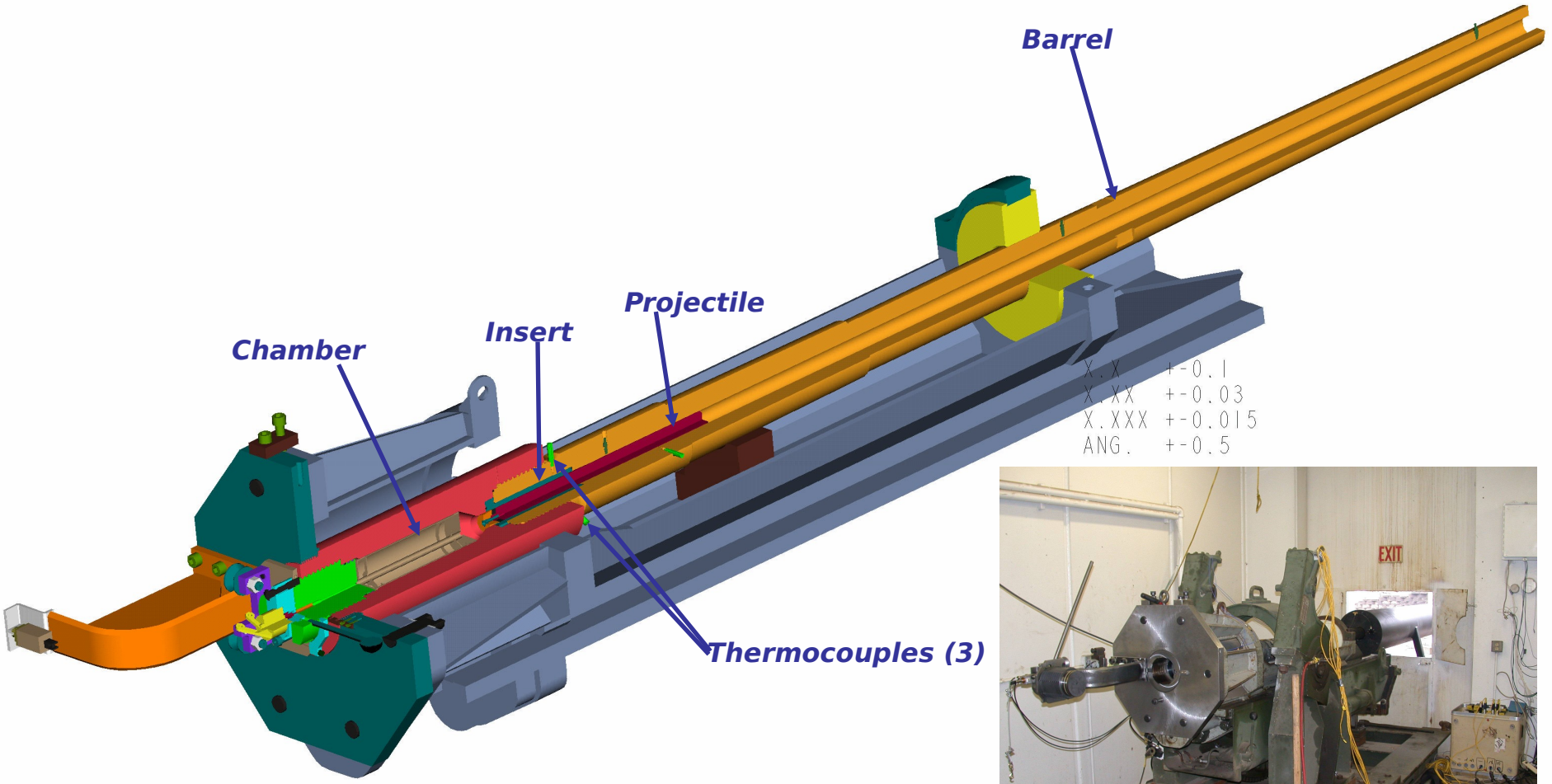

Screening Test Objective

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- The objective of the screening tests was to assess the candidate coatings under conditions similar to those of a large caliber gun barrel
- The test fixture design (i.e. gun), ballistic analysis, thermal analysis were iterated until the fixture replicated the environment within a large caliber gun barrel
  - Thermal response of a chrome lined insert simulates that of a large caliber gun barrel at the origin of rifle
  - Chemical reaction between gases and insert walls simulate that of a large caliber gun barrel
  - Mechanical loading of the insert simulates that of a large caliber gun barrel at the origin of rifle

Thermal Analysis Description

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- A United Defense proprietary gun barrel thermal model was used to predict temperature response within the 45 mm test fixture's insert
  - Same model used for AGS gun barrel thermal analysis
  - Generates an axially varying interior ballistic solution using XKTCNOVA
  - Uses ballistic solution to generate transient convective coefficients
  - Applies transient convective coefficients to the inner bore
  - Calculates temperature response of barrel and liner material

Thermal Analysis Results

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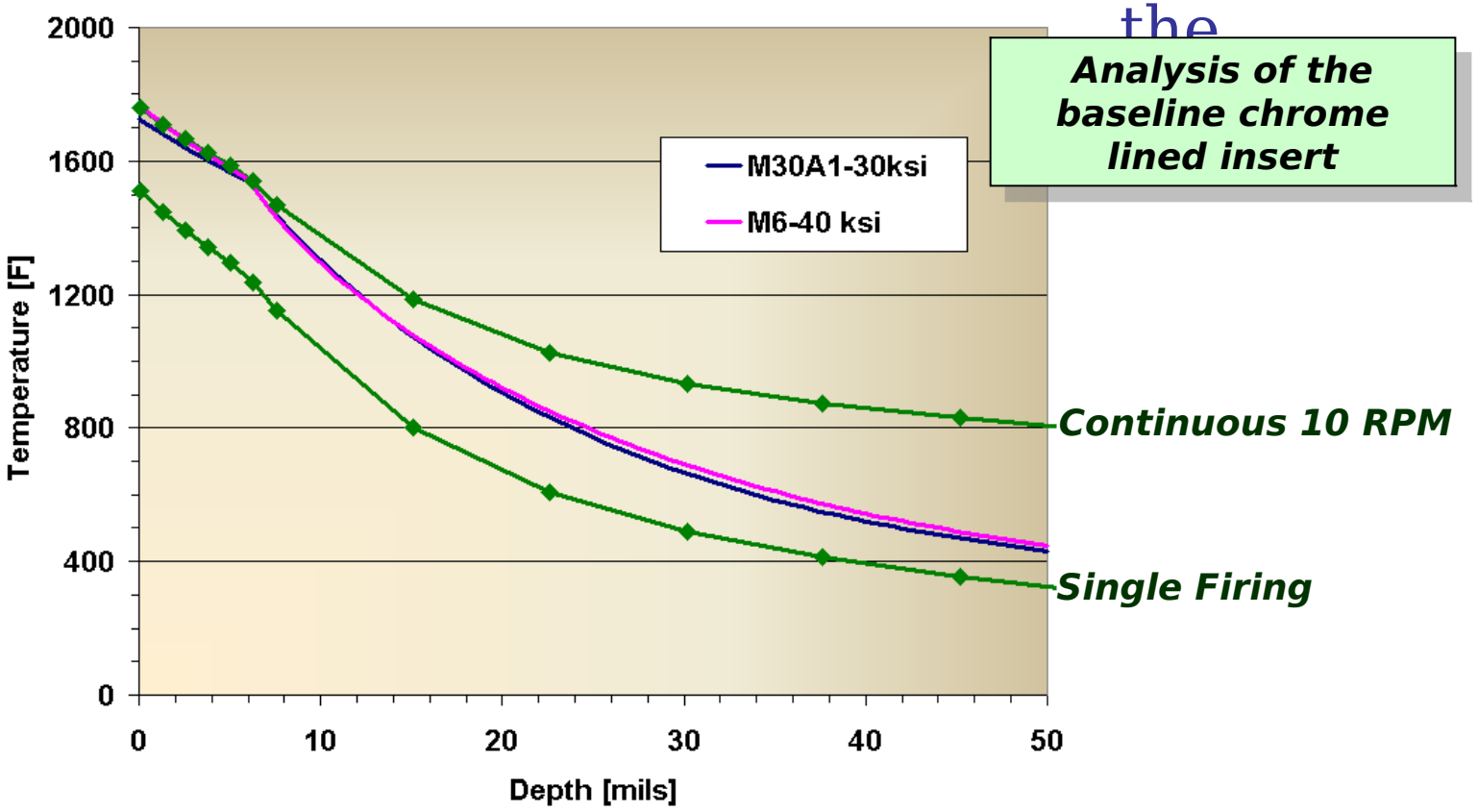
Test fixture design goal was to match the temperature profile from a large caliber gun with a single 45mm firing

Analysis indicated that two ballistic solutions woul the large



Resulting Fixture Design

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- Results of the thermal analysis indicated that two ballistic configuration would provide an acceptable match with the large caliber gun profiles
  - Option 1
    - 1.0 kg of M30A1 propellant (large caliber gun grain)
    - 10 kg projectile
    - 3 liter chamber
  - Option 2
    - 1.5 kg M6 propellant (large caliber gun grain)
    - 7.5 kg projectile
    - 3 liter chamber

Round Establishment Test

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- Prior to testing the candidate materials a series of firing were conducted to
  - Calibrate the thermal model
  - Select a ballistic (i.e. round) configuration
- 45mm round establishment tests
  - Conducted using a chrome lined insert
  - Thermal model calibrated “On the Fly” and used to guide selection of the propellant (mass and type) and projectile

Thermal Model Calibration

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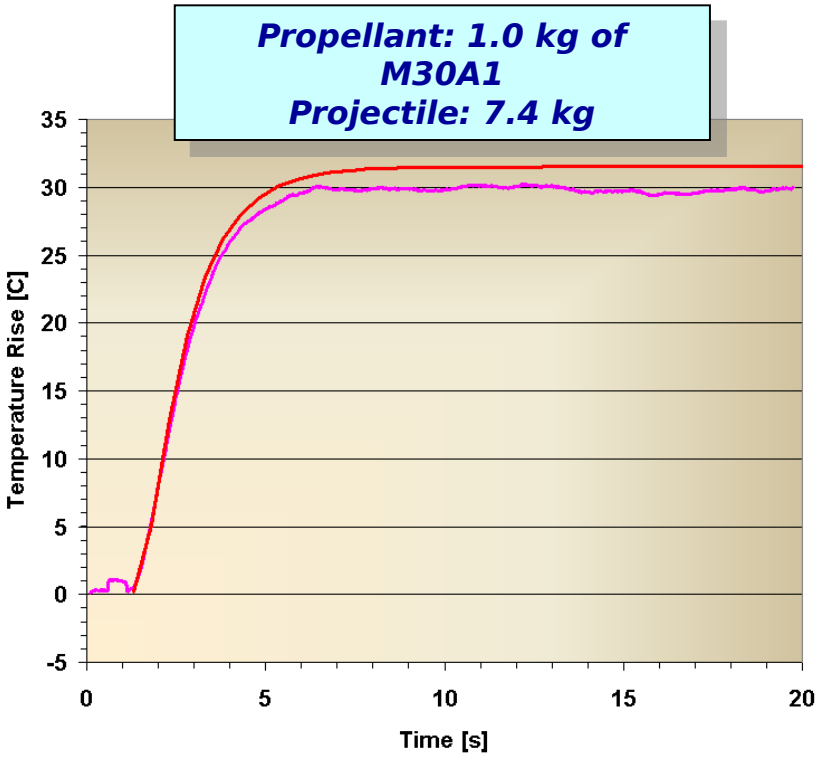

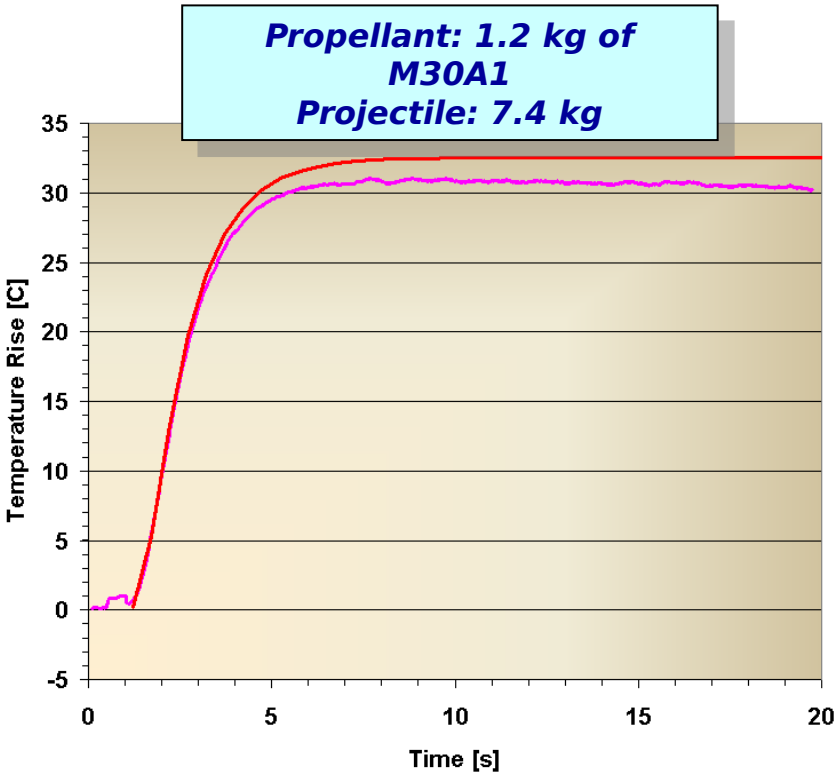

Thermal analysis conducted "On the Fly" to guide round configuratio

- ***Temperature measurements taken on back wall of insert (~0.4" from inner bore)***
- ***Thermal model predictions calibrated with measurements***
- ***Calibrated thermal model used to estimate "near bore" insert temperature response***

Near Bore Temperatures

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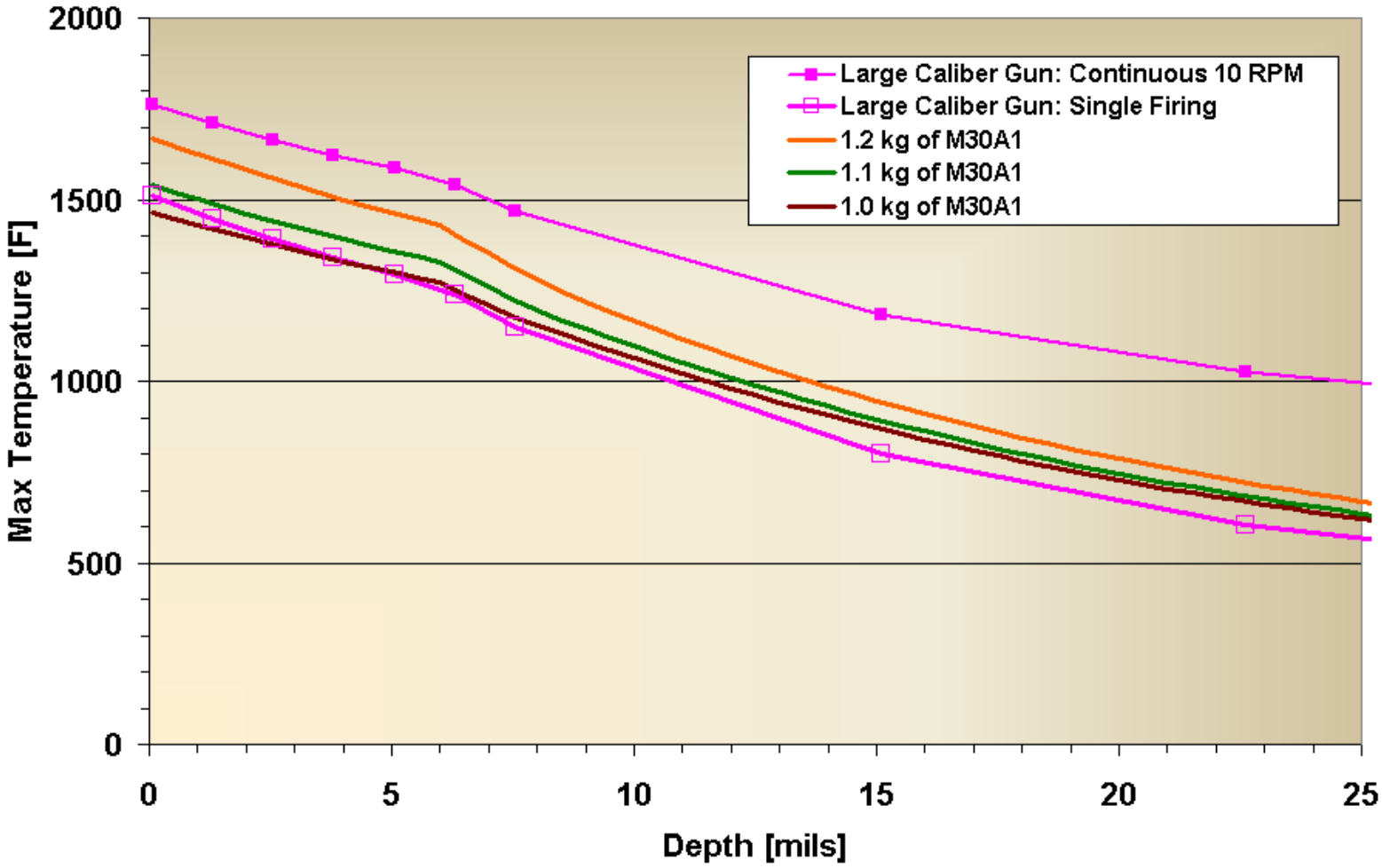

- *1.2 kg of m30a1 with 7.4 kg projectile ⇒ Acceptable agreem*
- *1.1 kg of m30a1 with 7.4 kg projectile ⇒ Marginally acceptal*
- *1.0 kg of m30a1 with 7.4 kg projectile ⇒ Marginally acceptal*

Further Thermal Model Calibration

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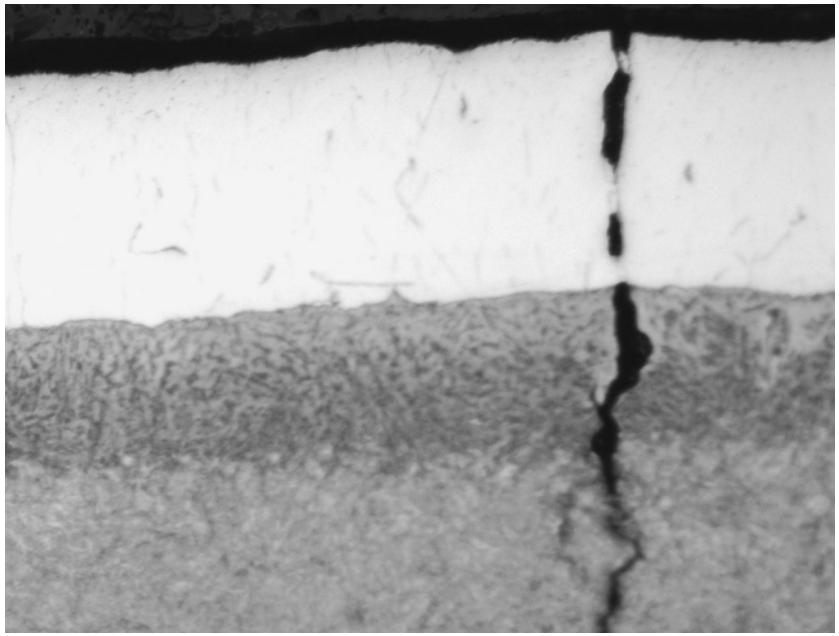
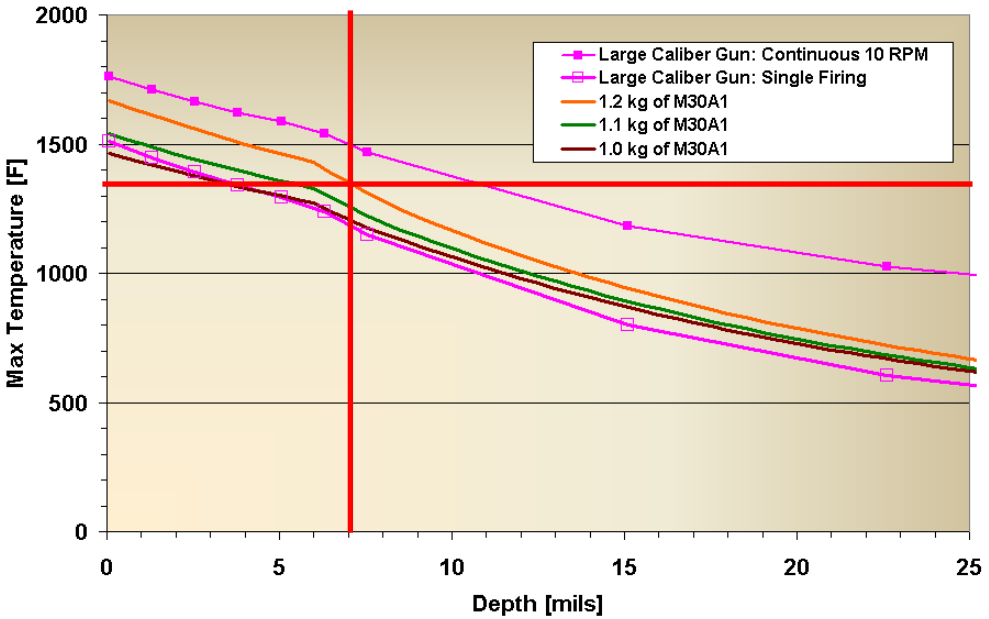
Round Establishment Tests: Chrome Lined Insert

Post-Test Material Inspection



Calibrated Thermal Analysis



Depth of thermally altered layer ≈ 7 mils

Steel transition temperature (1340°F) exceeded for depth < ~7 mils

Depth of thermally altered layer compares well with results of thermal ana

Selected Round Configuration

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- The calibrated thermal analysis indicated that 1.2 kg of M30A1 with a 7.4 kg projectile would provide the best possible match with that of 10 rpm continuous firings in a large caliber gun
  - Resulting operating condition was undesirable
- 1.0 kg of M30A1 with a 7.4 kg projectile was selected as the round configuration
  - Provided excellent match with the single firing large caliber gun temperature response
  - Resulted in acceptable operating conditions

Summary

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- A thermal analysis was performed to guide the design of a 45mm test fixture for the FNC / AGBT refractory coated barrel program
- The thermal analysis was successfully calibrated and used “On the Fly” to guide the selection of round configuration
- Analysis of results for the candidate coating materials is still in progress